

REMARKS

Applicants are amending their claims in order to further clarify the definition of various aspects of the present invention. Specifically, Applicants have amended claim 1 to recite that a first portion of the first diluted raw material gas is supplied into the inside of a reaction chamber through a mass flow controller; to recite in step (d) that the SiGe:C epitaxial layer or a SiGe:C-based epitaxial layer is formed using a gas containing germanium atoms and the first portion of the supplied first diluted raw material gas supplied through the mass flow controller; and to recite that a remaining second portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber through the mass flow controller, and is discharged without flowing through the mass flow controller. Note, for example, Fig. 9, and the description in connection therewith, in Section [0041] on pages 38 and 39 of Applicants' specification. Note, in particular, to be illustrative and not limiting, MFC12 in Fig. 9. See also Section [0045] on pages 41 and 42 of Applicants' specification.

It is respectfully submitted that amended claim 1 is directed to the elected invention and elected species, as elected in the Response filed June 27, 2008.

Initially, it is respectfully requested that the present amendments be entered. Noting, for example, Fig. 9 and portions of Applicants' specification referred to previously, clearly the present amendments do not raise any issue of new matter. Moreover, noting prior arguments made in the Amendment filed November 19, 2008, and clarification by the present amendments, it is respectfully submitted that the present amendments do not raise any new issues. Furthermore, by clarifying the supply of gas, it is respectfully submitted that the present amendments materially limit issues remaining in connection with the above-identified application; and, at the

very least, present the claims at least in better form for appeal. Clearly, the present amendments obviate the rejection under 35 USC 112, second paragraph, as discussed infra, and for this reason also, materially limit remaining issues. Noting clarification of arguments by the Examiner in the Office Action mailed March 3, 2009, it is respectfully submitted that the present amendments are timely.

In view of the foregoing, it is respectfully submitted that Applicants have made the necessary showing under 37 CFR 1.116(b); and that, accordingly, entry of the present amendments is clearly proper.

The rejection of claim 1 under the second paragraph of 35 USC 112, as being indefinite, the Examiner contending that claim 1 is indefinite "since it is not clear how to form SiGe:C epitaxial layer without supplying the gas comprising germanium", is noted. Claim 1 has been amended to recite that in step (d), a SiGe:C epitaxial layer or SiGe:C-based epitaxial layer is formed, using, inter alia, a gas containing germanium atoms. In view of this amendment of step (d) of claim 1, it is respectfully submitted that the rejection under the second paragraph of 35 USC 112 is moot.

Applicants respectfully submit that all claims presently being considered on the merits in the above-identified application patentably distinguish over the teachings of the references applied by the Examiner in rejecting claims in the Office Action mailed March 3, 2009, that is, the teachings of the U.S. patent documents to Sukegawa, et al., Patent Application Publication No. 2003/0162370, and to Takahashi, et al., Patent No. 6,306,211, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that these references as applied by the Examiner would have neither disclosed nor would have suggested such a manufacturing

method of a semiconductor device as in the present claims, including, after preparing a first raw material gas which contains a silane-based compound gas containing carbon atoms in a first hydrogen gas, and producing a first diluted raw material gas containing the silane-based compound gas with a second concentration lower than the first concentration by diluting the first raw material gas with a second hydrogen gas, supplying a first portion of the first diluted raw material gas into the inside of a reaction chamber in which is wafer to be processed is accommodated through a mass flow controller, with a remaining, second portion of the first diluted raw material gas not being supplied to the inside of the reaction chamber through the mass flow controller, this remaining second portion being discharged without flowing through the mass flow controller. See claim 1.

As will be discussed further infra, it is respectfully submitted that even assuming, arguendo, that the interpretation by the Examiner of the teachings of Sukegawa, et al. were correct, Sukegawa, et al. does not disclose, nor would have suggested, alone or in combination with the teachings of Takahashi, et al., wherein the remaining second portion of the first diluted raw material gas is discharged without flowing through the mass flow controller.

Furthermore, it is respectfully submitted that the teachings of these references as applied by the Examiner would have neither disclosed nor would have suggested such a manufacturing method of a semiconductor device as in the present claims, having features as in claim 1 as discussed previously, and, in addition, having features as in the other claims being considered on the merits in the above-identified application, including (but not limited to) wherein the remaining, second portion is discharged from a vent line (see claim 21); and/or wherein the first and second

hydrogen gasses have substantially the same concentration composition (see claim 3), with purity of the second hydrogen gas being 99.99% or more (see claim 4); and/or wherein the reaction chamber is an epitaxial layer forming reaction chamber of a single wafer epitaxial device (see claim 5); and/or wherein the epitaxial layer formed constitutes a portion of a base region of a HBT (see claim 7) or is a channel region of a strain SiGe-based MISFET (see claim 8); and/or degree of dilution of the first diluted raw material gas as in claims 9-12; and/or first concentration of the silane-based compound gas containing carbon atoms in the first hydrogen gas, as in claims 17-20.

The present invention is directed to a manufacturing method of a semiconductor device, effectively applicable to manufacturing a semiconductor device having SiGe:C formed using an epitaxial growth technique.

Various techniques have been proposed previously for producing, inter alia, SiGe:C, as described on pages 1 and 2 of Applicants' specification. SiGe:C can be used not only as material of, e.g., a base of a HBT, but also as a material of a channel of a MISFET, described in the paragraph bridging pages 2 and 3, and in the paragraph bridging pages 3 and 4, of Applicants' specification.

However, in forming SiGe:C by an epitaxial growth technique, oxygen-based impurities are detected in the formed product; and, as described in section [0009] bridging pages 4 and 5 of Applicants' specification, it has been found that the concentration of the oxygen-based impurity depends on the C concentration or the Ge concentration, and concentration of oxygen-based impurity is increased corresponding to an increase of the C concentration or the Ge concentration. Inclusion of such oxygen-based impurity raises various problems. For example,

when SiGe:C is used as a material of the base of a HBT, a lifetime of a carrier is reduced due to the oxygen-based impurity. Further, in SiGe:C, a stacking defect or the like attributed to the oxygen atom, a point defect, a line defect or a face defect is induced, and a current flows along an interface of the defect; this current cannot be controlled with a bias, and becomes a leaked current. Accordingly, use of SiGe:C in the base of the HBT or in the channel of the MISFET deteriorates reliability such as a breakdown strength of the HBT or the MISFET. Note section [0011] bridging pages 5 and 6 of Applicants' specification.

Against this background, Applicants provide a method avoiding problems as discussed previously, wherein concentration of the oxygen-based impurity contained in the SiGe:C which is formed by an epitaxial growth is reduced. Applicants have found that by performing the diluting as in the present claims, concentration of oxygen-based impurity can be reduced; and even when the formed SiGe:C is used as the material of the base of the HBT, it is possible to prevent lowering of a lifetime of a carrier attributed to the oxygen-based impurity, and, as a result, it is possible to enhance the hFE. Applicants have found that, even when the SiGe:C formed by the present invention is used as the material of the base of the HBT or the channel of an MISFET, a crystal defect attributed to oxygen atoms can be reduced, and, hence, a leaked current can be reduced, thus enhancing breakdown strength. Note section [0020] bridging pages 23 and 24 of Applicants' specification.

Thus, according to the present invention, the oxygen-based impurity contained in the formed SiGe:C can be reduced, without reducing the concentration of Ge or the concentration of C. Note sections [0044] and [0045] on pages 40-42 of Applicants' specification.

Furthermore, by supplying the first portion of the first diluted raw material gas into the inside of the reaction chamber through a mass flow controller, with a remaining second portion not being supplied to the inside of the reaction chamber through the mass flow controller, this second portion being discharged without flowing through the mass flow controller, gas flows can be more accurately and precisely controlled, without above-discussed impurities, further avoiding increase of oxygen-based impurity without reducing Ge and/or C.

It is emphasized that according to aspects of the present invention, the remaining second portion of the first diluted raw material gas, not supplied to the inside of the reaction chamber, is discharged without flowing through the mass flow controller, through which the first portion of the first diluted raw material gas is supplied to the inside of the reaction chamber. Accordingly, additional impurities flowing through the mass flow controller through which material is supplied to the surface of the wafer to be processed, from the remaining second portion of the first diluted raw material gas, can be avoided. Note, in particular, Section [0041] on pages 38 and 39 of Applicants' specification.

Sukegawa, et al. discloses a method of growing a mixed crystal layer, suitable for use in the vapor phase epitaxial growth of a silicon-germanium mixed crystal layer doped with carbon and boron as a base layer of a hetero-junction bipolar transistor. This patent document discloses that when the silicon-germanium mixed layer is grown using a silicon source gas, a germanium source gas, a first impurity source gas such as boron, and a second impurity source gas such as carbon for inhibiting the diffusion of a first impurity in the mixed crystal layer, the concentration of the second impurity is equal to or higher than the concentration of the first impurity

in a region at any given depth of the silicon-germanium mixed crystal layer. Note sections [0004] and [0013] on page 1 of Sukegawa, et al. See also Fig. 1 and the description in sections [0047] and [0048] on page 3 of Sukegawa, et al. Note disclosure therein that a gas supply pipe 12 is connected to the reaction chamber 1; and to the gas supply pipe 12, a gas cylinder 13, a mass flow controller 18, and a valve 23, which compose a silicon (Si) source gas supply unit, a gas cylinder 14, a mass flow controller 19 and a valve 24, which compose a germanium source gas supply unit, a gas cylinder 15, a mass flow controller 20, and a valve 25, which compose a boron source gas supply unit, and a gas cylinder 16, a mass flow controller 21, and a valve 26, which compose a carbon source gas supply unit, are connected in parallel via a valve 28, the valve 28 being connected to a dry pump 8 via a gas exhaust pipe 29, and selects whether to supply the respective source gasses to the reaction chamber 1 via the gas supply pipe 12 or exhaust them.

Attention is also respectfully directed to Fig. 10 of Sukegawa, et al., and the corresponding description in connection therewith in paragraphs [0084]-[0093] on page 6 thereof. As shown in Fig. 10 and described in paragraph [0086], a gas cylinder, a mass flow controller 31 and a valve 32 which compose a hydrogen gas supply unit are connected in parallel with the gas cylinder 16, the mass flow controller 21 and the valve 26 which compose the carbon source gas supply unit.

With respect to the first and second embodiments in Sukegawa, et al., shown respectively in Figs. 1 and 10 thereof, there would have been no disclosure or suggestion of producing the first diluted raw material gas and supplying a first portion of the first diluted raw material gas into the inside of a reaction chamber in which a wafer to be processed is accommodated, through a mass flow controller, and

wherein a remaining second portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber through the mass flow controller, and is discharged without flowing through the mass flow controller, as in the present claims, and advantages achieved thereby as discussed in the foregoing. In this regard, note that the Fig. 1 embodiment in Sukegawa, et al. does not form the diluted CH_3SiH_3 gas until the CH_3SiH_3 -containing gas is passed into the gas supply pipe 12, with all of the CH_3SiH_3 gas being passed through mass flow controller 21; and in Fig. 10, also, all of the CH_3SiH_3 gas is passed through mass flow controller 21, not being diluted until subsequent to passing through the mass flow controller 21.

Thus, it is respectfully submitted that Sukegawa, et al. would have neither taught nor would have suggested, and in fact would have taught away from, such process as in the present claims, including, inter alia, wherein a remaining second portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber through the mass flow controller, and is discharged without flowing through the mass flow controller.

Particularly noting location of mass flow controllers in each of Figs. 1 and 10 in Sukegawa, et al., as compared with locations of the mass flow controllers in Fig. 9 of the present disclosure, including MFC12, with, for example, the remaining second portion being discharged to vent line 12 from before MFC12, it is respectfully submitted that the disclosure of Sukegawa, et al. would have taught away from that aspect of the present invention including bypass of the mass flow controller by gas portions not to be supplied to the reaction chamber, and advantages achieved due thereto.

It is respectfully submitted that the additional teachings of Takahashi, et al. would not have rectified the deficiencies of Sukegawa, et al., such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

Takahashi, et al. discloses a method for growing a semiconductor film on a substrate using gasses, the method including steps of growing a doped semiconductor layer epitaxially over a substrate by supplying, onto the substrate, not only a source gas but also a gas containing a dopant by pulse flow at least once; forming a gate electrode on the doped semiconductor layer such that the gate electrode makes Schottky contact with the doped semiconductor layer; and forming source and drain electrodes on right- and left-hand sides of a gate electrode over the doped semiconductor layer such that the source and drain electrodes make ohmic contact with the doped semiconductor layer. Note the paragraph bridging columns 4 and 5 of this patent. See also column 3, lines 28-55, and column 4, lines 30-49. Note also Embodiment 2 in columns 12-14 of this patent, particularly from column 12, line 66, through column 13, line 36.

Even assuming, arguendo, that the teachings of Takahashi, et al. were properly combinable with the teachings of Sukegawa, et al., such combined teachings would have neither disclosed nor would have suggested the presently claimed invention, including, inter alia, wherein a remaining second portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber through the mass flow controller, and is discharged without flowing through the mass flow controller; and/or other features of the present invention as discussed previously, and advantages thereof.

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In view of the foregoing comments and amendments, entry of the present amendments, and reconsideration and allowance of all claims being considered on the merits in the above-identified application, are respectfully requested. In addition, upon allowance of claim 1, re-joining of the withdrawn claims 6 and 13-16, with allowance of these withdrawn claims in the above-identified application, are respectfully requested.

To the extent necessary, Applicants hereby petition for an extension of time under 37 CFR 1.136. Kindly charge any shortage of fees due in connection with the filing of this paper, including any extension of time fees, to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Account No. 01-2135 (case 1374.46346X00), and please credit any overpayments to such Deposit Account.

Respectfully submitted,

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